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Pasture Productivity Trial

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2017 PASTURE PRODUCTIVITY TRIAL

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Pasture is an essential component of the ration on organic dairy farms. Productivity of pastures is key to ensure the cattle have a plentiful source of high quality feed during the entire grazing season. Optimal management of pastures should include animal, plant, and soil factors. This project aims to identify weak links in the pasture system and evaluate the impact of adopting new strategies to overcome barriers to productivity. In this case, soil fertility was identified as the primary weak link to productivity.

The pasture where this research took place was seeded to grass about 30 years ago and prior to that had been used for corn silage. For the last 10 years, the pasture has been minimally fertilized with a spring or fall manure application at a rate of 3000-4000 gal ac^{-1}. The pasture consisted primarily of grass with low diversity and a very low percentage of legumes. This species scenario substantially increases the pasture demand for nitrogen (N). The long-term strategy to improve yield and quality included over-seeding the pasture to improve species diversity and ultimately provide higher yields and quality, which was done during June 2015. A goal was to increase legume percentage to minimize the need for N in the pasture system.

Our project focused on evaluating N fertility applications for impact on pasture yield and quality. Sodium nitrate (SN: 15-0-2), pelletized poultry manure (PM: 5-4-3), and a combination of SN and PM were used as fertilizer applications. Sodium nitrate has the advantage of only providing a readily available form of N. Other organic fertility sources generally release slowly over time and also contain additional nutrients like phosphorus (P) and potassium (K). Many organic dairy farmers in Vermont may have fields that are already high in P. In light of water quality regulations, farmers may need to seek ways to fertilize their fields without over-applying P in the form of organic fertilizers (manures, composts). Data was collected throughout the growing season to determine the impact of N fertility management strategies on pasture productivity.

MATERIALS AND METHODS

The project was conducted at Holyoke Farm located in St. Albans, VT. The soil type is a Massena stony loam and the soil test of the field indicated that P was at a low level and K were at a medium soil test level (Table 1).

Table 1. Soil quality characteristics, Holyoke Farm, St. Albans, VT, 2016.

pH	Organic matter	Phosphorus	Potassium	Calcium	Magnesium	Sodium	Aluminum
	%	ppm	ppm	ppm	ppm	ppm	ppm
6.5	4.8	1.6	53.8	1620	164	39	30.4

A base fertility application of solid manure at 8.5 tons ac^{-1} was applied in the fall of 2016, contributing 105 lbs ac^{-1} of total N, 69 lbs ac^{-1} of P, and 85 lbs ac^{-1} of K. In April, wood ash (5.1% soluble potash) was spread at a rate of 1650 lbs ac^{-1} over the 18-acre field, contributing 84 lbs ac^{-1} of K.

The experiment was implemented using a randomized complete block design. The experimental area was within the 18 acres of pasture that were grazed by 60 cows using management intensive grazing techniques. Cows were given approximately 1 acre of pasture, representing 1 paddock, for every 24 hours that they grazed. Through the course of the season cows grazed the 18 acres six times. For the experiment, a portion of one paddock was divided into plots 10'x20' in size. The experiment had three fertilizer treatments and one un-fertilized control. Fertilizer treatments consisted of 1) SN, 2) PM, and 3) SN + PM. Allganic brand sodium nitrate from the SQM Company (Atlanta, GA) and Kreher Family Farm (Clarence, NY) 5-4-3 poultry manure were sourced for the project. General plot information is shown in Table 2.

Table 2. General plot management, St. Albans, VT, 2017.

Trial Information	Holyoke Farm St. Albans, VT
Soil type	Massena stony loam 0-3% slope
Previous crop	Permanent pasture
Plot size (ft)	10 x 20
Grazing cycles	May – October, six cycles
Fertilizer application dates	15-Jun

The application rate of SN and PM was based on crop removal rates of the pasture. Nitrogen was applied based off of crop removal rates for intensively managed grass pasture across the entire season, which is 145 lbs N ac^{-1}. Organic standards only allow using SN to meet 20% of crop N removal rates, at most, which equaled to 29.0 lbs N ac^{-1} or a total of 193 lbs ac^{-1} of SN product. For the SN only treatment, this was the only fertilizer applied. The rate of PM application was matched to the crop removal rate of P (57.5 lbs P ac^{-1}). This was to replicate scenarios where over-application of P is of strong concern, and this equaled to 1438 lbs ac^{-1} of PM. For the PM only treatment, this was the only fertilizer applied. For the SN + PM treatment, the rate of SN and PM described above were both applied. An overview of all treatments used in both experiments is shown in Table 3.

Table 3. Pasture productivity trial treatments, St. Albans, VT, 2017.

Treatment	Total product applied	Nitrogen rate	Phosphorus rate	Potassium rate
	lbs ac^{-1}	lbs ac^{-1}	lbs ac^{-1}	lbs ac^{-1}
Sodium nitrate (SN) 15-0-2	193	29.0	0	4
Kreher's poultry manure (PM) 5-4-3	1438	71.9	57.5	43.1

Sodium nitrate 16-0-0 **AND** Kreher's poultry manure 5-4-3 SN + PM	193 1438	29.0 71.9	0 57.5	4 43.1
Control	None	None	None	None

Fertilizer treatments were applied in one application. The application was completed on 15-Jun, after the 2nd grazing cycle. Fertilizers were broadcast by hand.

Soil nitrate-N samples were taken prior to the first and third grazing cycle and after the sixth grazing cycle. Pasture plots were sampled by clipping the contents within two 0.5 m^2 quadrats per plot just before each grazing cycle to determine biomass yield and quality. Samples were dried until they reached a stable weight and then sent to Dairy One Forage Laboratory (Ithaca, NY) for wet chemistry analysis of crude protein (CP), net energy lactation (NE_L), relative feed value (RFV), and neutral detergent fiber (NDF), and calcium, phosphorus, magnesium, potassium, and sodium concentrations on a dry matter basis.

The bulky characteristics of forage come from fiber. Forage relative feeding values (RFV) are negatively associated with fiber since the less digestible portions of plants are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF). This fraction includes cellulose, hemicellulose, and lignin. Because these components are associated with the bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows.

Net energy of lactation (NE_L) is calculated based on concentrations of NDF and acid detergent fiber. NE_L can be used as a tool to determine the quality of a ration. However, it should not be considered the sole indicator of the quality of a feed as NE_L is affected by the quantity of a cow's dry matter intake, the speed at which her ration is consumed, the contents of the ration, feeding practices, the level of her production, and many other factors.

Results were analyzed with an analysis of variance in SAS (Cary, NC). Pasture yield and quality data was analyzed from the third grazing cycle in July till the sixth grazing cycle in October. The first (May) and second (June) grazing cycles were not included in analysis, since plots did not receive the fertilizer treatment until after the second grazing cycle. The Least Significant Difference (LSD) procedure was used to separate cultivar means when the F-test was significant ($p < 0.10$).

Variations in yield and quality can occur because of variations in genetics, soil, weather and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real, or whether it might have occurred due to other variations in the field. At the bottom of each table, a p-value is presented for each variable (i.e. yield). The p-value represents the probability that there was an effect from the treatment. The lower the p-value, the greater the probability that the treatment had an effect on the variable (i.e. yield).

Also at the bottom of each table, a LSD value is presented for each variable (i.e. yield). Least Significant differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In this example, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

Variety	Yield
A	6.0
B	7.5*
C	9.0*
LSD	**2.0**

RESULTS

Throughout the growing season, temperature and precipitation varied compared to 30-year historical averages. May-August was wetter than normal, receiving 4.99 more inches of precipitation as compared to historical averages (Table 4). Temperatures in May-August were cooler than normal by an average of 1.1° F per month. The tail end of the season was dry and warm, with September and October receiving 2.11 fewer inches of rainfall than normal and being an average of 6.48° F warmer than usual per month. Overall, there were an accumulated 2580 Growing Degree Days (GDDs) from May to October, approximately 256 more than the historical average; however, much of the heat came at the end of the season.

Table 4. Seasonal weather data collected in Alburgh, VT, 2017.

Alburgh, VT	May	June	July	August	September	October
Average temperature (°F)	55.7	65.4	68.7	67.7	64.4	57.4
Departure from normal	-0.75	-0.39	-1.90	-1.07	3.76	9.20
Precipitation (inches)	4.10	5.60	4.90	5.50	1.80	3.30
Departure from normal	0.68	1.95	0.73	1.63	-1.80	-0.31
Growing Degree Days (base 50°F)	245	468	580	553	447	287
Departure from normal	47	-7	-60	-28	129	175

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink 80 logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Pasture yield and quality differences between fertilizer treatments

The SN + PM treatment had the highest dry matter yield and had the greatest crude protein content; however, in spite of this advantage, the other two fertilizer treatments yielded statistically comparably (Table 5). Treatments also affected crude protein content, with the PM and SN + PM treatments being the top performers. No significant differences were seen between treatments for NDF, NE_L, or RFV. Overall, adding additional fertility to the pasture increased yield by an average 268 lbs ac^{-1} per grazing cycle.

Table 5. Fertilizer treatment effect on pasture yield and quality from July – October, post-fertility application on 15-Jun, St. Albans, VT, 2017.

Treatment	Yield	Crude protein	NDF	NE_L	RFV
	lbs ac^{-1}	% of DM	% of DM	Mcal lb^{-1}	
SN	1032*	16.8	53.1	0.605	113
SN + PM	**1180**	18.4*	51.6	0.616	116
PM	1080*	**18.5**	51.0	0.620	118
Control	829	16.2	52.4	0.592	114
p-value	0.005	0.001	0.208	0.123	0.373
LSD	158	1.09	NS	NS	NS
Trial mean	1030	17.5	52.0	0.608	115

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

The PM treatment was among the top performers for calcium and P content in pasture (Table 6). The SN + PM treatment performed comparably for P. All three fertilizer treatments outperformed the control for K content. No significant differences were seen between treatments for magnesium or sodium content in pasture.

Table 6. Fertilizer treatment effect on pasture nutrient quality from July – October, post-fertility application on 15-Jun, St. Albans, VT, 2017.

Treatment	Calcium	Phosphorus	Magnesium	Potassium	Sodium
	% of DM	% of DM	% of DM	% of DM	% of DM
SN	0.561	0.412	0.242	2.46*	0.042
SN + PM	0.515	0.431*	0.235	**2.63**	0.037
PM	**0.561**	**0.441**	0.249	2.57*	0.028
Control	0.550*	0.388	0.245	2.38	0.025
p-value	0.101	0.006	0.633	0.092	0.179
LSD	0.035	0.026	NS	0.183	NS
Trial mean	0.537	0.417	0.243	2.51	0.033

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

The starting grazing height and post-grazing height of the pasture was statistically similar between the treatments (Table 7). However SN and SN + PM showed the greatest height difference between pre- and post-grazing. This may indicate that cows preferred the treatments with the SN or it may indicate that overall, these treatments had more additional forage to graze.

Table 7. Fertilizer treatment effect on height to which pasture was grazed from July – October, post-fertility application on 15-Jun, St. Albans, VT, 2017.

Treatment	Pre-grazing height	Post-grazing height	Pre-post height difference
	inches	inches	inches
SN	13.1	6.76	5.47*
SN + PM	14.0	6.84	**6.88**
PM	12.4	7.42	4.49
Control	12.4	6.33	4.98
p-value	0.154	0.603	0.079
LSD	NS	NS	1.57
Trial mean	13.0	6.84	5.45

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Pasture yield and quality differences between grazing cycles

Greatest pasture yields occurred July – September; however, greatest pasture quality (CP, NDF, NE_L, RFV) generally occurred in October (Table 8). Interestingly, the CP concentrations were highest in July reflecting the additional fertility added through the SN and PM. Thus, it would seem that the benefit of these fertility sources is seen most immediately by their effect on protein.

Table 8. Grazing cycle effect on pasture yield and quality, St. Albans, VT, 2017.

Cycle	Yield	Crude protein	NDF	NE_L	RFV
	lbs ac^{-1}	% of DM	% of DM	Mcal lb^{-1}	
July	1150*	**20.2**	51.4	0.601	116
August	**1180**	14.4	53.6	0.602	112
September	1140*	16.0	54.1	0.598	111
October	644	19.3*	**49.2**	**0.633**	**122**
p-value	<0.0001	<0.0001	<0.0001	0.024	0.003
LSD	158	1.09	1.68	0.021	5.42
Trial mean	1030	17.5	52.0	0.608	115

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).

Generally, greatest pasture nutrient content (calcium, phosphorus, magnesium, and potassium) also occurred in October (Table 9).

Table 9. Grazing cycle effect on pasture nutrient quality, St. Albans, VT, 2017.

Cycle	Calcium	Phosphorus	Magnesium	Potassium	Sodium
	% of DM	% of DM	% of DM	% of DM	% of DM
July	0.523	0.380	0.218	2.50	**0.072**
August	0.534	0.330	0.203	2.24	0.02328
September	0.503	0.418	0.269*	2.41	0.016
October	**0.585**	**0.543**	**0.281**	**2.89**	0.021
p-value	0.0021	<0.0001	<0.0001	<0.0001	<0.0001
LSD	0.035	0.026	0.018	0.183	0.014
Trial mean	0.537	0.417	0.243	2.51	0.033

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).

The tallest pasture, both pre-grazing and post-grazing was generally seen in July and cows grazed down the pasture by the greatest height in July, in comparison with other graze times during the season (Table 10).

Table 10. Grazing cycle effect on height to which pasture was grazed, St. Albans, VT, 2017.

Cycle	Pre-grazing height	Post-grazing height	Pre-post height difference
	inches	inches	inches
July	14.8*	**7.81**	**6.96**
August	**15.1**	---	---
September	11.5	6.62	4.90
October	10.6	6.08	4.50
p-value	<0.0001	0.050	0.009
LSD	1.27	1.17	1.36
Trial mean	13.0	6.84	5.45

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).

Pasture yield and quality impact from the interaction of fertilizer treatment and grazing cycle

There was no significant treatment by grazing cycle interaction for yield indicating that the treatments performed similarly regardless of grazing cycle. There was a treatment by grazing cycle interaction for CP and NEL (Figure 1, 2).

Overall, the control treatment had the lowest CP and NE_L in July and August. However, as the season progressed the CP and NE_L were similar to the levels found in the fertility treatments. This likely indicates that the fertility treatments had the largest impact on CP just following the application of the treatments.

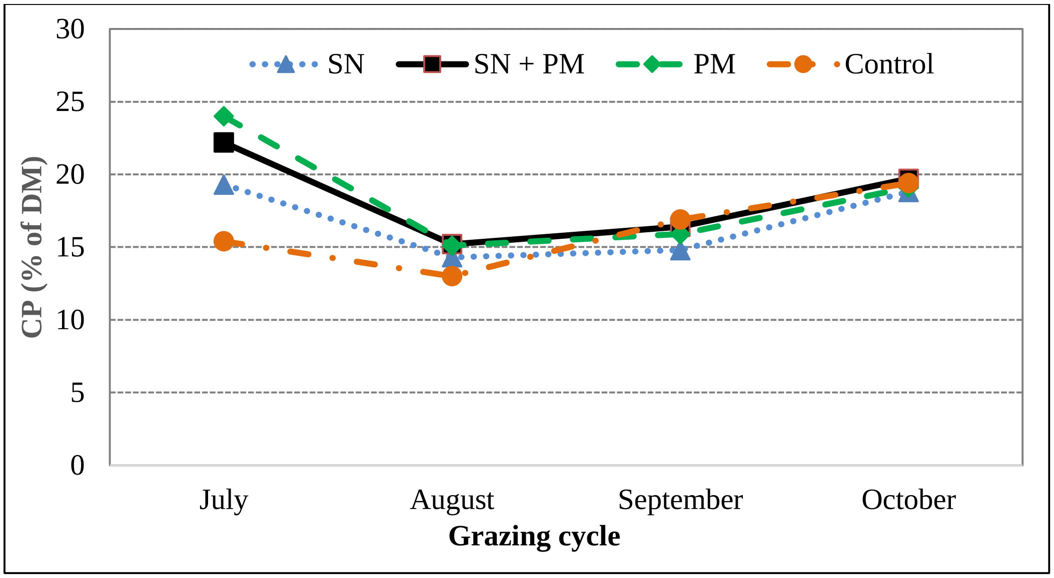

Figure 1. The effect of fertilizer treatment and grazing cycle on crude protein (p=0.0005), St. Albans, VT, 2017.

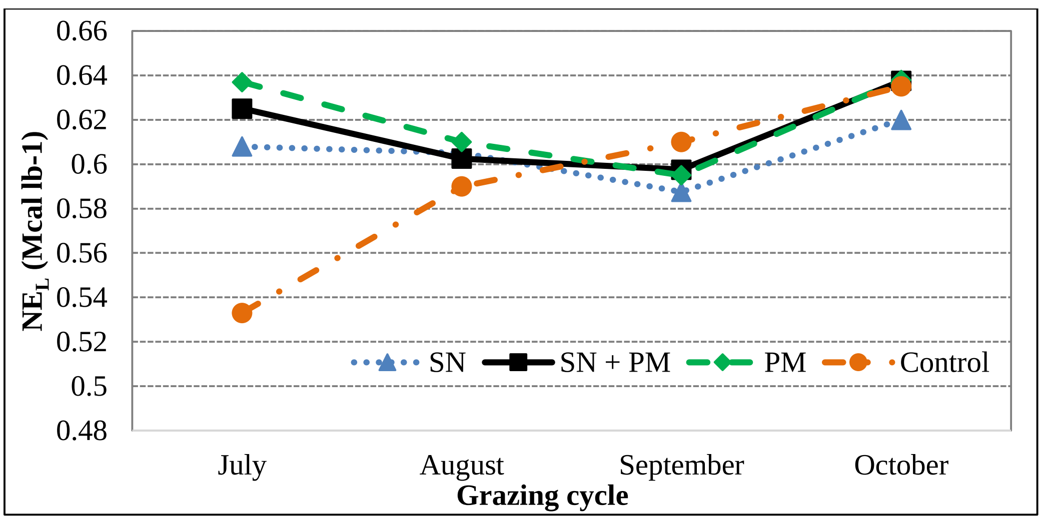

Figure 2. The effect of fertilizer treatment and grazing cycle on NE_L (p=0.067), St. Albans, VT, 2017.

Pasture yield and quality differences between fertilizer treatments, within grazing cycles

There were no significant yield differences between fertilizer treatments within any of the grazing cycles (Table 11).

Table 11. Fertilizer treatment effect on pasture yield during each of the grazing cycles, no significant differences, St. Albans, VT, 2017.

Treatment	July	August	September	October
	Yield, lbs ac^{-1}			
SN	1190	1130	1120	691
SN + PM	1390	1360	1210	761
PM	1090	1260	1320	659
Control	957	992	900	465
p-value	0.260	0.423	0.130	0.267
LSD	NS	NS	NS	NS
Trial mean	1150	1180	1140	644

NS – There was no statistical difference between treatments in a particular column (p=0.10).

There were significant quality differences between fertilizer treatments within the July and August grazing. There were no significant quality differences between fertilizer treatments within the September or October grazing.

For the July grazing cycle, the PM fertilizer treatments significantly increased CP, P, and K content in the pasture compared to the other treatments (Table 12).

Table 12. Fertilizer treatment effect on pasture quality during the July grazing cycle, St. Albans, VT, 2017.

Treatment	Crude protein	Phosphorus	Potassium
	% of DM	% of DM	% of DM
SN	19.3	0.348	2.39
SN + PM	22.2*	0.415*	2.66*
PM	**24.0**	**0.443**	**2.82**
Control	15.4	0.315	2.15
p-value	<0.0001	0.0007	0.0212
LSD	2.00	0.0421	0.337
Trial mean	20.2	0.380	2.50

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).

For the August grazing, the fertilizer treatments outperformed the control for the CP content in the pasture (Table 13).

Table 13. Fertilizer treatment effect on crude protein content in pasture during the August grazing cycle, St. Albans, VT, 2017.

Treatment	Crude protein
	% of DM
SN	14.3*
SN + PM	**15.2**
PM	15.1*
Control	13.0
p-value	0.062
LSD	1.41
Trial mean	14.4

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).

DISCUSSION

The crop nutrient recommendations based on the soil test appear in Table 14. In general, the highest amount of N applied came from the SN + PM treatment. It makes sense that this combined treatment would likely provide a yield and quality boost to the pasture. However, it should be noted that although the PM application contained 72 lbs ac^{-1} of actual N, only roughly one third of that total would be plant available in the first year. Overall, it was clear that adding fertility to pastures could boost both yield and protein of the pasture. Protein increases appeared to occur within the first few months following application where yield benefits were seen for 4 months following applications. A total yield increase of 1075 lbs ac^{-1} per year was observed by adding fertility.

Timing within the season also affected yield and quality, with the October grazing generally having the best quality while July-September had the highest yields. High quality in October could be related to growth stage at grazing or cooler weather present during that month. When examining specific grazing cycles, there was a significant, positive effect from fertilizer treatments on pasture quality during the July and August grazing cycles, which was probably in response to the fertilizers having just been applied on 15-Jun.

Table 14. Nutrient balance from the sodium nitrate treatment, St. Albans, VT, 2017.

		Nitrogen	Phosphorus	Potassium
		lbs ac^{-1}	lbs ac^{-1}	lbs ac^{-1}
Soil test recommendation	**Pasture, intensive grazing**	100	35	180
Nutrients supplied	**SN treatment**	29.0	0	4
Nutrient balance	**SN treatment**	-71.0	-35	-176
Nutrients supplied	**PM treatment**	71.9	57.5	43.1
Nutrient balance	**PM treatment**	-28.1	+22.5	-136.9
Nutrients supplied	**SN + PM treatment**	100.9	57.5	47.1
Nutrient balance	**SN + PM treatment**	+0.9	+22.5	-132.9

Note: A negative number indicates a nutrient deficiency.

With pelletized PM priced at \$0.25 lb^{-1} and SN priced at \$0.53 lb^{-1}, the price to fertilize per acre is listed in Table 15. The cost per pound of applied N is \$3.53 for SN, \$5.00 for PM, and \$4.58 for SN + PM. Some of these fertilizer treatments may be feasible for pasture-based dairy farmers, however, one also needs to consider the amount of time taken to apply the fertilizer and one would want to verify the potential benefit of the application.

Table 15. Costs for each fertilizer treatment, St. Albans, Vermont, 2016.

Treatment	Product applied	Cost
	lbs ac^{-1}	\$ ac^{-1}
Sodium nitrate (SN) 15-0-2	193	102
Kreher's poultry manure (PM) 5-4-3	1438	360
Sodium nitrate (SN) 15-0-2 **AND** Kreher's poultry manure (PM) 5-4-3	193 1438	462

These results only represent one year of data at one location. This trial aimed to evaluate improving pasture productivity by targeting soil fertility, while avoiding an over-application of P. The cost of purchased N sources in organic systems may outweigh the benefit realized from the application. In this study, a small increase was seen in yield and quality compared to no additional N amendments (outside of farm manure). The most cost effective way to improve pasture yields and reduce N requirements of pasture is to maintain legumes in the pasture mix. More research is needed to evaluate best fertility management strategies for this situation.

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